Two complexities

The need to link complex thinking and complex adaptive systems science

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Abstract

This article reflects the division in the field of the study of complexity, between a mainly philosophical and epistemological approach (Edgar Morin called it "general complexity") and a mainly scientific and methodological approach (called by Morin as "restricted complexity"). The first perspective would be well represented by Morin's "complex thinking," while the second by the new "science of complex adaptive systems." We show the potential and limits of each perspective, and conclude by claiming the need to relink both the perspectives into a comprehensive "paradigm of complexity" that is capable of providing, and following the original definition of Thomas Kuhn, at the same time a worldview ("general complexity") and examples of scientific achievements ("restricted complexity").

Introduction

According to Edgar Morin [21], we can distinguish between the two approaches to the phenomenon of complexity: "general complexity" and "restricted complexity."

On the one hand, a "general complexity," is a fundamentally epistemological approach developed by scientists and philosophers such as Edgar Morin, Ilya Prigogine, Heinz von Foerster, Humberto Maturana, Francisco Varela, among others. It was developed primarily between the 70s and 80s from new disciplines such as cybernetics, systems theory, dissipative structures theory, catastrophe theory or autopoiesis theory. Morin's *complex thinking* would be one of its best syntheses.

On the other hand, a "restricted complexity," is a primarily methodological approach developed by scientists such as Murray Gell-Mann, John Holland, Stephen Wolfram, Stuart Kauffman, and Robert Axelrod since the creation in 1984 of the Santa Fe Institute in the United States and the improvement and sophistication of computational technologies. *Complex Adaptive Systems Science* is currently its dominant trend.

"General complexity" approaches the phenomenon of complexity from a natural language. It draws its epistemological implications from the point of view of the subject who knows: complexity would compose a "new paradigm" [21] or "new alliance" [23], which is potentially transdisciplinary. Therefore it gives a theoretical account of the properties of self-organization and autonomy of the physical, biological, and social systems from the perspective of the process of their observation. Complexity would express the extent of ignorance of an observer who is unaware of the information of the observed system itself [2] and the process of "construction" [9] of an external object that is unattainable by the cognitive system of a subject. It is characterized more by their own "operational closure" and "internal consistency" [24] than by the faithful representation of the external reality. This approach, going back to the historic Macy Conferences (1946-1953) on Cybernetics [7], was widely developed in the 70s since the transition from a "first-order cybernetics" or cybernetics of observed systems [27] to a "second-order cybernetics" or "cybernetics of observing systems" [9].

Complexity, at the same time, expresses the self-organized and systemic nature of the world and the cognitive limits of human observers and it would call into question the deterministic, reductionist, and positivist principles of classical science. This approach has even included ethical proposals through authors such as Edgar Morin or Fritjof Capra. For these authors, the "paradigm shift" would not only have epistemological implications and imply the change of view of science or reality, but it would have ethical implications that tend toward a more harmonious relationship with nature, other people, and cultures from a "holistic" or "systemic" capability. Such a capability, integrating several complementary elements, makes up the biosphere and the entire humanity into a harmonious whole.

"Restricted complexity," instead, approaches the phenomenon of complexity from a formal language by trying to model using new computational techniques. It models are based on, such as cellular automata or multi-agent simulation [17], the "objective" and "observable" global structures and functions emerging in unpredictable dynamic "complex adaptive systems" [10,12] of the physical, biological and social, by means of the local interaction of its components. The restricted complexity algorithms are radically different from the classical science algorithms that are based on linear systems and differential equations. The methodology of simulation employed in restricted complexity shows the limits on cognition and prediction capabilities of the modeler. The structures and functions of the systems overcome the human computing capabilities and emerge as "surprising" [29] or "counterintuitive" [3] computational outcomes. A widely extended interdisciplinary project of research on modeling and simulation of complex systems has been launched since the foundation of the Santa Fe Institute in 1984, the first center exclusively devoted to the study of complex systems [25].

Unlike general complexity, restricted complexity is encouraged by the classical scientific spirit, and it does not cross the scientific borders. It looks closer at the hidden regularities of complexity and the refinement, as much as possible, of complex system modeling.

There is a deep separation between these two ways of approaching the phenomenon of complexity. Each has its own references, schools, publications, and conferences. Each is presented as exclusive and often neglects or ignores the other. Many, who work in one, do not know the other, and *vice versa*. This scenario of dichotomy and polarization seems to contradict the very meaning of complexity as the linking of opposing and complementary principles, and demands a reunification of both perspectives in the context of a comprehensive paradigm of complexity including a "worldview" and "models of scientific realizations" [16], the two dimensions of a paradigm according to [15].

Then, we are going to show the potential of each perspective and its limits that reclaim its reunification with the opposite perspective.

General complexity: Potential and limits of a complex thinking

"General complexity" comprises a broad community of philosophers, thinkers, and scientists from many different disciplines and fields of knowledge. The *complex thinking* of Edgar Morin would be the perfect synthesis of this transdisciplinary epistemic perspective (Morin, 2005a). Morin has generated a school of thought that extends all over the world and, especially, in Latin America, Mexico, Brazil, and Argentina, among other countries. He is one of the best examples of the proponents of "general complexity." His main work, *La Méthode*, is comprised of six volumes and it extends complexity from the physical and biological sciences to the social sciences and the "noology" and finally to ethics. Morin in his books constructs a paradigm of *self-eco-re-organization* and a world *genesic loop*, the tetragrammaton *order-disorder-interaction-organization*. With great and encompassing epistemic vision, Morin provided a glimpse of the foundations of a *new paradigm of complexity*, with implications that are not only scientific and philosophical, but also social, political, cultural and economic. He poses a new kind of harmonic relationship with the world that comes from the discovery of complexity in science (Morin, 2008). The three fundamental principles that guide complex thinking are the followings: the *hologrammatic principle* (according to which not only the part is in the whole but the whole is also in the part), the *dialogical principle* (according to which two principles could be at the same time antagonistic and complementary), and the *recursive principle* (according to which, following a generating loop, the products and effects are themselves producers and causes of what produces them). Complex thinking deeply confronts the principles of reduction, disjunction, and determinism of the classical noncomplex science dating back to Galileo and Newton, which is prior to the "paradigm shift" advanced by information theory, cybernetics, and systems science. It finally confronts the central classical principle of objectivism and separation between the subject and object. With a strong influence of quantum physics, it explores how the object is inseparable from the subject, how the observed system is the construction of the observer, and not an external and objective reality.

Nevertheless, this extraordinary epistemological construction currently loses solidity in its methodological base. For Kuhn, foremost, a paradigm is represented by examples of scientific achievements, both concrete and formalized. Morin and many of the authors who fit into the general complexity approach have not fully incorporated the latest (for many, the definitive) wave of complex systems science with its new methodologies of cellular automata, multi-agent systems, swarm intelligence, neural networks, fuzzy logic, genetic algorithms, and so forth. Its natural language cannot incorporate the positive contributions of these methodologies and that is where we discover its limits.

The thinkers of the "general complexity" certainly share a new worldview of extraordinary scope, a discursive horizon based on the problem of complexity, pointing to "holistic" principles such as system, relationship, entanglement and inseparability (operating from physics to ethics). However, generally, they do not share the formal models and examples of scientific achievements that, in the words of Kuhn, define the paradigm. Those models and examples are brought currently by the science of complex adaptive systems. The thinkers of complexity rarely refer to models such as cellular automata, genetic algorithms, agent-based simulations, self-organized criticality, autocatalytic sets, small worlds or scale-free networks. There are also no allusions to mathematical patterns of complexity, such as the "power law," observable in many complex systems, from the pile of sand to the fluctuations in the stock market, from world wars to traffic jams.

To support our thesis, we must say that the community of complex thinkers does not find its place as well within the mainstream philosophy that is too identified with the "history of philosophy" precisely because it is located in a "no man's land" between science and philosophy (Morin, 1982), thereby, proposing transdisciplinary approaches. Thus, we find that the integration on it of the contents of complex systems science seems its natural derivation, precisely because complex thinking is not a philosophy, but rather a reflection of the scientific discovery of the issue of complexity. This "new science" invites philosophical reflection as suggested by the work of some of its principal authors, such as Gell-Mann, Kauffman or Wolfram.

We note that, in complex thinking, too much emphasis is on the *discursive* aspects of the paradigm of complexity rather than on their *scientific* aspects. This has led to a focus on the applications of complex thinking in the field of *education*. Complex thinking is being used in education reform, in new pedagogic lines, introducing transdisciplinary models or curricula typically focusing on complex issues such as sustainability or eco-human relations, especially in Latin America. This application, otherwise capital and crucial for a new holistic and necessary worldview, ignores, however, that complex thinking is also strongly rooted in science, in contemporary new science, so that in addition to these interesting applications, it would be interesting to incorporate, without losing critical thinking, the contributions of the new sciences of complexity.

We will give two examples of two central pillars of the great paradigmatic construction of Morin which in our opinion should be updated based on the major contributions of the new science of complexity: the concepts of Agent and Complex Systems derived from *agent-based modeling* and the concept of Complex Network derived from *complex networks analysis*.

The introduction of the concept of Agent becomes essential in the new science of complexity. However, it is absent from Morin's famous "tetralogical loop," presented in the first volume of La Méthode and composed of the terms order/disorder/interaction/organization, creator of complexity as well as the source of the universe's evolution. However, Morin does not include in his paradigm a fifth term that would constitute its culmination at the light of the latest wave of complex systems science: the *agents*, the main element based on whose local interactions with the environment occur the evolution and complexity of the organizational systems. Instead of a "tetralogic loop," we propose then a "*pentalogic* *loop*": *order/disorder/agents/interactions/organization*. The brilliant intuition in Morin was prior to the emergence of the science of complex adaptive systems and multi-agent models, so that the absence of the term agents is explained by chronological reasons. The logical thread of complexity, providing the backbone of the successive volumes of *La Méthode* is represented by the guideline of *biology*. However, since the work of Gell-Mann and Wolfram and the emergence of new disciplines such as sociophysics or econophysics, currently complex systems science and the science of complex networks is largely led by physicists, being *physics* and namely *statistical physics*, the new guideline rather than biology. This new guideline difference emphasizes, more than the organizational structures, the micro movements of the agents components that generate macro effects in the systems.

It is of great interest to rework the concept of the Complex System in complex thinking from the contributions of the new science of complex adaptive systems. It is not so much an organizational structure that gives order to a set, as interpreted by Morin, as a variable scheme of adaptation and learning to changing environments that is operated by nonlinear interacting agents (the notion of complex system as "adaptive scheme" comes from Gell-Mann). That is, a concept closer to Henri Atlan's principle of "complexity from noise" than to Varela and Maturana's theory of "autopoiesis," which has to do more with a "process" of complexity than with a "state" of complexity. The Complex System adjusts with the theory of evolution [6], which is precisely one of the major theoretical frameworks absent from the vast Morinian construction of *La Méthode*. It must have been a tome that Morin himself announced but never came to conclude and add to his saga, which was entitled *Le devenir du devenir*.

The reconceptualization of the Agent and Complex System in line with current science should redirect the discourse of complex thinking, yet without falling either on the simplifications that the new science brings and that we will present hereinafter.

Concerning the complex ethics, which can be considered the "ending point" of all *La Méthode*, we also miss the greater reference to the concept of Complex Network and to the new science of networks [4,26] and, in particular, Duncan J. Watts's theory of "small worlds". The complex ethics, as complex thinking, has scientific roots. In addition, the complex systems science continues to bring us examples in line with such complex ethics, which posits a higher linkage of human beings to each other and to the planet as a whole. We note here how Morin's complex thinking, incorporating concepts such as "world-society" or "planetary society" (Morin, 2001) as emerging signs of this deep and unavoidable linkage (Morin, 2005), does not refer to what constitutes today the "complex scientific principle " at the base of his theorizing of human linkage and all "world-society" or "planetary society": the *science of complex networks*. We can conceive a Complex Network as the topological structure of Complex Systems. A Complex System is ultimately a Complex Network of interactions among agents. A Complex Network is a network that has nontrivial topological properties, halfway purely ordered networks and purely random networks (in that stadium between order and disorder where, according to Langton, the computation of information is maximized). Most biological, social, ecological and technological networks are complex networks. The complex social network model of Watt's "*small worlds*" demonstrates the extreme connectivity of these complex networks and the society we live in, one of their best examples: just a short chain of six people separating an individual from any another in our world ("*six degrees of separation*"). This counter-intuitive extreme connectivity of the nodes of complex networks would be such a scientific support of legitimacy of a complex ethic that includes a fundamental human linkage, pointing to a change of the structure of an anthropo-social system that is still guided by the illusion of extreme atomism and individualism. This would be, therefore, a paradigmatic example of the scientific substrate that we need to reintroduce in complex thinking and ethics.

In summary, we believe that complex thinking should be opened to the science of complex systems and draw on it in their discursive horizons, while maintaining and reinforcing its broader epistemological scope. As we shall see, the models of this complex systems science are certainly simplified models of a much larger complexity. However, given the growing number of research centers dedicated to complex systems, publications, research projects, and so forth, it represents a major advance in understanding the complexity as very important, and to take into account integration in the theoretical discourses of complexity.

Restricted complexity: Potential and limits of complex adaptive systems science

The “restricted complexity” is composed of a community of scientists who share various theories and methods, and who work on the basis of examples and models (from the pioneering models of Turing machines and von Neumann’s self-reproductive automata, to recent models such as Stephen Wolfram’s cellular automata, John Holland’s genetic algorithms or John Conway’s “game of life”). These apply to the search for resolutions to new problems in terms of physics, biology or sociology [5,25]. The paradigm that runs through these practices is the paradigm of *cellular automata* (the core matrix or formal logic of all these expressions). Cellular automata, a mathematical model devised by von Neumann, is a universal Turing machine with a universal computing power that explains natural phenomena that had escaped traditional mathematics based on differential equations. Cellular automata are *discrete dynamical systems* that are modeled by using a computer. These systems are composed of elements or “cells” that follow simple rules of local interaction (where the future state of each cell is conditioned by the present state of their neighboring cells) and are iterated and elicit the emergence by self-organization of complex macrostructures that are not reducible or explainable locally. *Agent-based modeling*, the main methodology used in “restricted complexity” that comes from Distributed Artificial Intelligence, would not be more than a more sophisticated extension of cellular automata, which gives more autonomy to the elements of the system, to recreate the fittest environments of Artificial Life or Artificial Societies [11].

Complex Adaptive Systems (CAS) is the best example of this new trend in complexity science that allows, for the first time, modeling and visualizing complexity through very advanced computer techniques. CAS, launched approximately since the foundation of the Santa Fe Institute in 1984, is an emerging scientific field that is increasingly gaining academic recognition. There is a worldwide proliferation of interdisciplinary institutes and scientific journals dedicated to the study of complex adaptive systems. This prolific community working with the paradigm/model of the cellular automata is actually only partially aware of sharing a “new paradigm” (called by them as “emergentist”), with its inevitable “metaphysical” component, derived from the cellular automata model itself, which contrasts with the classical paradigm still prevailing in the reductionist science. In addition, it is not aware of sharing a worldview that spread over multiple *philosophical, epistemological and ethical implications* (the science of complex systems does not enter in this field and retracts to the epistemic cuts of the classic paradigm). Its perspective is often more “scientist” than “scientific” (but not always, the formidable work of Stuart Kauffman is an example of an exception to this rule, but also a minority example within the science of complex systems). Moreover, despite its extraordinary progress, the scientific community of complex systems is still a minority subsystem of the general scientific system, so it also runs the risk of being subsumed as another branch of the “normal science,” which is its paradigmatic root that is unable to define new social discourses that structure the overall social system differently.

CAS fits a first-order cybernetics, becoming a science of the *observed* complex adaptive systems (a “first order” science of complex systems), from which is expurgated the epistemological problems made evident by the second-order cybernetics and by complex thinkers such as von Foerster, Varela, Maturana, Luhmann or Morin. Therein, the entire context of punctuation (distinction/indication) of systems by observers/modelers is removed. There is a predominance of the algorithm over the subject. Complex problems are primarily problems of “objective” adaptive evolution that are expressed by algorithms. Nevertheless, the “meaning” of the algorithm is always a function of a subject. Thus, the formation of complex structures within the random walk, as is the case for example of highways in the ants model of Langton only makes sense for an individual observer who cuts “qualitative and subjective” spatiotemporal discrete forms from a continuous background. The probabilistic algorithm realizes the lack of information on the observed system, but eliminates the principle of reflexivity of the subject of his systematic process of problem solving, while the human reflexive observer is present at each stage as the last substrate (substrate of meaning) of all algorithms. The random algorithm is not absolute, but “relative” to the subject observer. The subject is both the condition of possibility of the algorithm and its intrinsic “epistemic limit.” This observer/subject as shown by von Foerster, Maturana and Varela, is a cognitive system characterized by an operational closure, which relates more to his mindset and his own internal subjective coherence than to the objective and accurate representation of the external real. Nevertheless, the algorithm seeks always to be “objective” and ignores this decisive presence of the subject (builder/interpreter/limiting) in all knowledge. They aspire to a “representation” of the real and not so much to a “construction,” and it is even ignored by the arbitrariness intrinsic to modeling. The fundamental idea of von Foerster is not taken into account: how computation is always computation of *a* reality (constructed by the observer/modeler) and not of *the* reality (of reality itself, which is always “impossible” in the words of Luhmann). Are the models, models of the world or models of our spirit projected on to the world? Are we not replacing the territory for a map? Moreover, if all reality is a model, a model of reality such as CAS could actually be considered the *model of a model*, a double construction. There is finally a missing third element to explain what constructs the common and intersubjective “reality.” It is “society” for von Foerster: the “scientific community” in the case of science. However, this “social” construction of reality within the scientific society sends us directly to the question of the “paradigms,” issue retracted by the science of complex adaptive systems (at least beyond the dichotomous debate on reductionism/emergentism).

Simulated artificial systems are finally closed systems that are preconceived by the modeler/programmer, systems with fixed borders, and cuts on a continuous background. Natural systems, such as agencies or societies, are instead open systems that are without defined borders. The subject behind the model and artifice is again expelled. There is no principle of reflexivity; the dominant principle is the classical principle of objectivity. From this point of view, CAS articulates with the worldview of the classical mechanics, and not with the new one of quantum mechanics, which marked the turning point in science to complex thinking.

Complex systems are somewhat autonomous “masters of their own sense” [8] unlike artificial complex systems that are modeled. The complexity and this information would be internal to the system itself, and that the external observer cannot grasp. CAS cannot avoid heteronomous maneuvers and operations on autonomous systems. Thus there would not be “authentic self-organization” in simulated complex systems. There is an effective absence of the complex property of “creation of novelty” [1] in these artificial systems, a property that manifests the complex system resistance to any *a priori* law, that is, all confinement in a given program, whether evolutionary or not (the evolutionary programming does not generates any true evolutionary novelty). This property of novelty creation is the expression of the “creativity of the universe” [14,13], which is not reducible to algorithms. In multi-agent models creativity would not be “real.” Creativity is less prevalent in Artificial Societies, where the Castoriadis’s property of the imaginary, the anthropo-social property of creation *ex nihilo*, is of course absent. Any “emergence” (like self-organization, randomness, and creation) is somehow already included in the initial programming of the model, with fixed *a priori* rules.

CAS often confuses “complexity” (not algorithmizable, irreducible) with “complication” (algorithmizable, reducible). Thus, living and social systems would resemble more to the simulated complicated systems, constructible by man, whose structure is ultimately knowable and describable by a Turing machine (even if the huge computational time makes the system seem “complex” for the observer). However, real living and social systems are complex systems, ie systems whose comprehensive knowledge by the observer is inseparable from a deep fundamental ignorance of information that we do not have, in accordance with the continuing creativity of such systems.

CAS models ideally should be as simple as possible, as evidenced by the “KISS principle,” (*keep it simple, stupid*) [3]. The complex aims to be explained by the simple. It is considered that only “the complex emerges from the simple,” and that there is an emergence in complex systems of adaptive structures and global functions from the iteration (thoughtless, mechanical) of simple local rules of interaction. However, what may perhaps be admitted to the physical and biological levels, it becomes rather "reductionist" in the socio-anthropological level, where we can say both that "the complex emerges from the simple" and that "the complex emerges from the complex," where Agents are not only mechanisms (or trivial machines) but self-reflexive Subjects (non-trivial machines). A revolution is by instance an emergence of formidable complexity through the nontrivial and strongly complex consciousness of the subjects that make up the system: the ability of the elements of the system to change reflexively the structure of the system [28]. This does not prevent in any case that, within a society, we can also observe phenomena of emergence of the complex from the simple as in the classical segregation model of Schelling, the "Beach Problem" of Miller and Page or in the self-organization of cities and vehicle flows, for instance.

The science of complex systems poses in short a non-deterministic epistemological background, but it therefore does not address the ultimate ideal of complexity, implicit in their probabilistic models, and defined as what is beyond our knowledge, something that is well expressed by Morin, among others. The modeled complex systems represent only cuts and discretizations of a treelike continuum of complexity. These maps produce specific "micro-territories." However, these maps are often identified with the global territory, which can only be understood from a generalized complex thinking. At the crossroads of the object and the subject, complexity has, in sum and at the same time, an objective dimension (likely to be modeled) and a subjective dimension (requiring an epistemological holistic vision). Thus, becomes necessary to integrate the wider epistemological horizon of complex thinking in complex systems science, constituting both an *epistemic loop* that is endlessly forwarding complex thinking to the complexity science, and *vice versa*.

Towards a comprehensive paradigm of complexity

We need to come back to the original definition of paradigm in Thomas Kuhn. According to him, a paradigm is composed by examples of scientific achievements and by a worldview.

In June 2009 I had the opportunity to take part in organizing a symposium in which we sought to take a step towards what is proposed in this article: the integration of the two complexities in a comprehensive complexity paradigm, an integration of scientific examples of complexity ("restricted complexity") and a new worldview of complexity ("general complexity"). Thanks to the Edgar Morin Centre of the École des Hautes Etudes en Sciences Sociales (EHESS) in Paris, the Fondation des Sciences de l'Homme and a group of heterodox scholars from the University College London, we implemented a first Symposium on Complex Systems Modeling and Complexity Thinking. The event took place on June 15, 2009 at the Maison Suger in Paris.

We wanted to commemorate the 25th Anniversary of the pioneering Symposium of the United Nations University (UNU) held in Montpellier (France) in 1984 on "Science and Praxis of Complexity," which brought a spectacular cast of personalities, including Prigogine, Boulding, Pribram, Luhmann, Atlan, Dupuy, Morin, Le Moigne, and Costa de Beauregard, among others. That historical event coincided precisely with the creation that same year, of the Santa Fe Institute, and thus the new "science of complex adaptive systems." Among the speakers at the symposium were Edgar Morin, Jean-Louis Le Moigne, Denis Noble, Nigel Gilbert, Sylvia Nagl, Robert Biel, and Basarab Nicolescu.

We put face-to-face at one table, representatives of the "general complexity" and of the "restricted complexity."

I want to conclude this article with an example of the possibility of working in the direction of building a complex paradigm that integrates the two complexities. Epistemology and methodology of complexity should be brought together in order to understand both the objective and the subjective dimensions of complexity. Maybe only then, when we will succeed, we will begin to see a new horizon of hope as recited by Morin in many works, [22,19,18] a new horizon for the planet? Thus, we understand that the horizon of the construction of a comprehensive complexity paradigm is the same as the utopian horizon of the complex ethics, because only then complexity will be fully realized and will become a new paradigm that structures science and society as a whole in a more fair and healthy way.

The famous verses of Machado, cherished by Morin, adopted as its motto, say: "*walker, there is no path, the path is made by walking*". In this article I have sought to present the projective horizon of a comprehensive complexity paradigm towards which to walk, to build on our walk, a holistic paradigm of complexity that would go through the necessary integration of complex thinking and science of complex adaptive systems. This text has been as an invitation to join the construction of such integrated complexity paradigm.

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